Permian deposits of Sicily: a review

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ABSTRACT
The complex tectonostratigraphic setting of the Permian rocks of Sicily is outlined in the light of the large mass of new stratigraphic and paleontologic data recently collected by several researcher groups. The Permian deposits occur mostly as tectonic *mélanges* imbricated in the thrust pile forming the Sicilian fold and thrust belt. Also Mesozoic and Tertiary uncompetent rocks can be found in these *mélanges*. Several lithostratigraphic units were differentiated among these mostly siliciclastic and clastic-carbonate deep-water deposits, spanning in age from Kungurian up to Changxingian. The Permian deposits are regarded as the originary sedimentary substrate of the deep-water mesocenozoic domains of Sicily. Fossil associations, facies and ages of these deposits are consistent with the existence of a wide and persistent deep-water basin located along the Africa margin since, at least, the early Permian time and connected to the main Tethyan domains.

KEY WORDS
stratigraphy,
paleogeography,
Permian,
western Sicily.

RÉSUMÉ
L'arrangement tectonostratigraphique complexe du Permien de la Sicile est défini à partir de nombreuses données stratigraphiques et paléontologiques récemment collectées par différents groupes de chercheurs. Les dépôts du Permien surviennent le plus souvent comme des mélanges tectoniques, avec quelquefois des roches mésozoiques et tertiaires, imbriqués dans des piles d'unités tectoniques formant la chaîne sicilienne. Plusieurs unités lithostratigraphiques, principalement constituées de dépôts silicoclastiques et clastiques-carbonatées de mer profonde, datées du Kungurien au Changxingien, ont été différenciées. Ces dépôts constituent le substrat sédimentaire des bassins méso-cénozoiques de la Sicile. Les associations de fossiles, le faciès sédimentaires et l'âge des terrains permiens indiquent l'existence d'un bassin ample et persistant, localisé le long de la marge africaine depuis, au moins, le Permien inférieur et relié avec les principaux domaines téthysiens.

MOTS CLÉS
stratigraphie,
paléogéographie,
Permien,
Sicile occidentale.

INTRODUCTION

In the Sicilian fold and thrust belt strongly tectonized Permian-Triassic deep-water deposits occur as either duplexes or *mélanges* imbricated with tectonic units of basin-derived Mesozoic and Tertiary rocks. A large amount of new stratigraphic data was collected in this last decade from these deposits, poorly exposed in the Lercara region and in the Sosio Valley (Catalano, Di Stefano & Kozur 1988, 1989, 1991 and references therein, 1992; Senowbari-Daryan & Di Stefano 1988; Kozur 1989a, b, 1991a, b, 1993a, b; Kozur & Mostler 1989; Di Stefano 1990; Flügel, Di Stefano & Senowbari-Daryan 1991 and references therein; Gullo & Kozur 1992). Some new lithostratigraphic units were differentiated. New Lower and Middle Triassic rock units were described from the Sosio Valley. Also the stratigraphic and paleoenvironmental evaluations of the famous Sosio Limestones (Gemmellaro 1887-1899) were revised (Di Stefano 1990; Flügel *et al.* 1991).

Figure 1 is a simplified structural sketch-map of Sicily showing the location of the geologic section in figure 2 and of the stratigraphic columns in figure 4: a = Lercara-Roccapalumba-Vicari area; b = Sosio area.

GEOLOGIC SETTING

The Permian rocks from the Lercara and Sosio Valley areas are incorporated in the Sicanian thrust system, an external element of the Sicilian chain (Catalano *et al.* 1993, 1995). This tectonic element consists of basin-derived thrust sheets that are arranged with an overall foreland vergence and minor back thrusts (Sicanian units in Figs 1, 2). The Sicanian thrust system is buried in central Sicily beneath a thick allochthon consisting of deformed foreland and satellite-basin deposits of Neogene age and outcrops again in eastern Sicily in the Mount Judica area. It overthrusts southwards more external platform-derived tectonic units (Saccense-Hyblean units) as well as the deformed syntectonic covers (Fig. 2). The Sicanian thrust sheets are derived from the deformation of a sedimentary multilayer, consisting of up to 2000 m of Upper Paleozoic to Tertiary deep-water deposits that accumulated in a southern Tethyan domain loca-

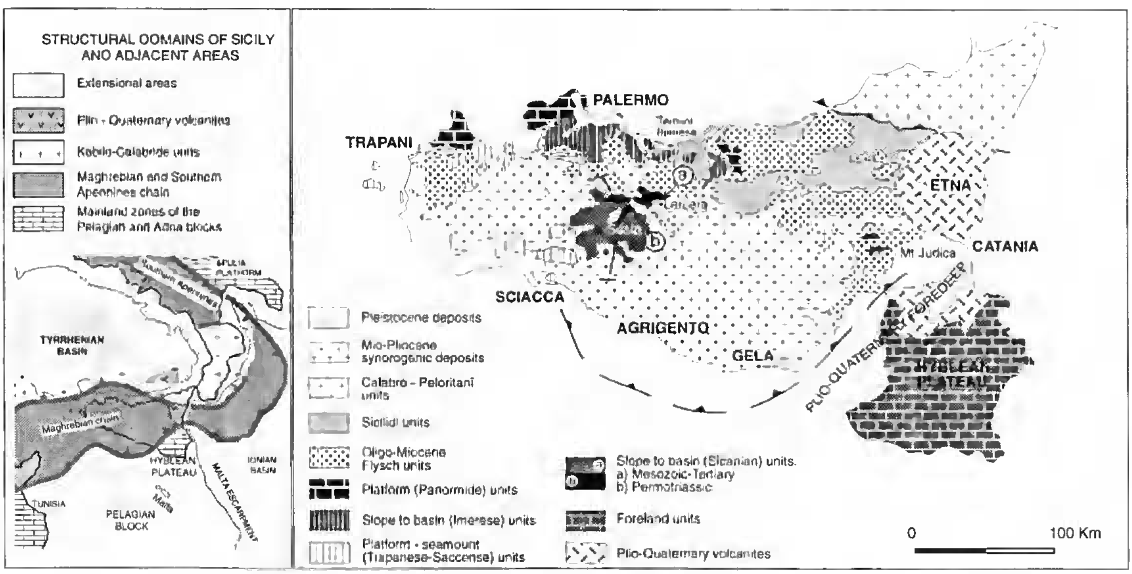

FIG. 1. — Main structural domains of the central Mediterranean area and structural sketch of Sicily (modified from the Structural Model of Italy sheet No. 6).

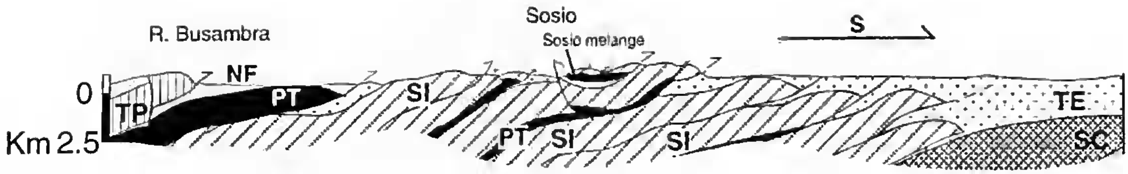

FIG. 2. — Interpretative geologic section across the Rocca Busambra-Sicani Mountains area based on surface data (location in Fig. 1): **TP**, Trapanese units (Late Triassic-Miocene); **NF**, Numidian Flysch units (Late Oligocene-Early Miocene); **SI**, Sicanian units (Late Triassic-Early Tertiary), **PT**, Permian-Carnian units; **SC**, Saccense units (Late Triassic-Miocene); **TE**, Oligo-Miocene, mostly terrigenous, deformed covers. The thick allochthon of Permian-Carnian deposits dipping below the Rocca Busambra Unit represent the westward extension of the Lercara structure.

ted along the African margin (Sicanian Basin, *sensu* Di Stefano 1990, Catalano *et al.* 1991). Because of the Neogene compression this multilayer was detached from its original (unknown) substrate. According to Catalano *et al.* (1993, 1995), it was deformed into three different duplex stacks consisting of Paleozoic-Carnian, Late Triassic-Paleogene and Neogene rocks respectively.

In the Lercara area the Permian rocks occur in a large antiformal structure, up to 3000 m thick, consisting of Permian and Triassic rock slices alternating, in places, with thin slices of Miocene clays. The extension at depth of the structure is documented by seismic and exploration well data (Roccapalumba 1 well, Caflisch & Schmidt di Friedberg 1967). The repeated imbrication of Permian and Triassic rocks in the Lercara structure provides evidence of a duplex-type deformation in the Permian to Carnian interval of the Sicanian sedimentary multilayer. The first deformation of the Sicanian allochthons is generally considered to be no older than Tortonian (Mascle 1979; Catalano & D'Argenio 1982) even though a possible older age (Lower Miocene) for the duplex accretion was suggested by Vitale & Giambrone (1992). The Lercara structure is inflected northwards below Numidian Flysch units as well as Trapanese platform units and overthrusts southwards more external Sicanian allochthons (Fig. 2). The upward-arching and emplacement of the structure is due to later (Pliocene) transpressional deformation as indicated by the involvement of the Upper Tortonian-Lower Pliocene syntectonic covers in arching as well as in breaching thrusts.

In the Sosio area the well-known Permian limestone megablocks (Gemmellaro 1887) were considered sedimentary klippen in Carnian beds (Mascle 1979). We now believe that the Permian to Carnian rocks outcropping in this area, comprising the Permian to Middle Triassic deposits described by Catalano *et al.* (1988, 1991), are part of a tectonic *mélange* (here indicated as Sosio mélange), which is related to the Neogene compression and imbricated in the Sicanian thrust pile (Fig. 2). This *mélange*, up to 500 m thick, indicates *décollement* or floor-thrusts along which the Late Triassic-Tertiary sequences have been detached from the Permian-Triassic substrate. It overthrusts the Oligo-Miocene deformed cover of a lower unit and is overlain by a duplex structure composed of Upper Triassic-Eocene cherty limestones.

Besides the Lercara and Sosio areas, siliciclastic deposits of supposed Permian age, containing elements of algal-oolitic limestones, were described in the Cozzo Rasolocollo area, south of Termini Imerese (Broquet 1968). Until now no biostratigraphic data confirming a Permian age have been obtained from these rocks. They form, together with Carnian *Halobia*-bearing marls and calcilutites, a thick allochthon crossed by the exploration well Cerda 1 for about 3300 m. According to Rocco & Giartosio (1961) evidence of Permian rocks could be found only in the deepest part of this well.

Permian and/or Lower Triassic rocks could also be present in the subsurface of the Hyblean foreland, in south-eastern Sicily, as suggested by magnetic and gravimetric data (Bianchi *et al.* 1989).

PERMIAN LITHOSTRATIGRAPHIC UNITS

The stratigraphic reconstruction of the Permian successions from the Lercara and Sosio areas is very difficult due to:

1. The strong deformation affecting these mostly incompetent rocks.

2. The poor exposures: only a few small and discontinuous sections can be observed.

3. The facies types, which consist of mostly siliciclastic/carbonate turbidites containing a large mass of reworked lithoclastic and bioclastic material.

4. The lack of stratigraphic relations among the different lithologic units, the contacts generally being tectonic.

Aware of the above limitations which have led to debate about the age of the siliciclastic rocks of the Lercara area (*see* Ruggieri & Di Vita 1972; Cirilli *et al.* 1990), we recognize the following lithostratigraphic units, whose thickness is quite impossible to be estimate. In figure 4 we have preferred to present the different rock units in separate columns, but we believe they belong to different depositional areas of a single sedimentary basin. The Permian chronostratigraphic scale of Kozur (1989a, c) is used, tentatively correlated with the proposed time scale adopted for the Peri-Tethys program and map.

Kungurian Flysch (Catalano *et al.* 1991)

This is the oldest Permian lithostratigraphic unit. It was recognized in the Roccapalumba, Lercara and Vicari areas and consists of a thick package of deep-water siliciclastic turbidites characterized by reddish shales, siltstones and micaceous sandstones displaying Bouma divisions, flute casts and *Nereites* ichnofacies. The sandstones contain abundant quartz and muscovite and subordinate biotite, feldspars and rare zircons (Broquet 1968). A Late Artinskian-Kungurian age of these deposits is supported by conodonts (Catalano *et al.* 1991). Calcareous turbidites are frequently interbedded. They consist of skeletal-lithoclastic grainstones/packstones with fusulinids, *Tubiphytes* sp., *Archaeolithoporella* sp., dasycladacean algae (*Mizzia* sp., *Epimastopora* sp.) and sponge fragments.

Magmatic rocks (diabases and lamprophyres) are present in the flysch deposits. Also a small laccolitic body consisting of a sodic-differentiated alkali-syenite is present in the Torrente Margana area, about 10 km west of Lercara (Vianelli 1970). No age determinations of these magmatic rocks are available. They could also be younger than Permian.

Intercalations of coarse calcareous debrites in the siliciclastic turbidites also occur in places. A large spectrum of facies-types can be recognized in the debrite elements. Shallow-water pebbles and boulders consisting of sponge/*Tubiphytes* boundstones, *Tubiphytes*/*Archaeolithoporella* bindstones, phylloid algae boundstones, *Mizzia*-fusulinid grainstones-packstones, and crinoidal packstones are commonly found (Senowbari-Daryan & Di Stefano 1988). A Lower Permian age of these elements is indicated by algal assemblages and fusulinids as *Pseudofusulina (Leeina) kraffti* Schellwien and *P. vulgaris* Schellwien (Flügel *et al.* 1991).

Large boulders of deep-water dark-grey ammonoid-brachiopod-crinoidal bearing wackestone-packstone are also present, in unclear relationships with the flysch deposits. Conodonts of Chihsian age were found associated to albaillellacea radiolarians, ammonoids, scolecodonts, linoproductid brachiopods and trilobites (Catalano *et al.* 1991).

Younger Permian rock packages are exposed in the Sosio Valley area, along the Torrente San Calogero (Catalano *et al.* 1988, 1989, 1991, 1992) as well as in the famous limestone megablocks.

San Calogero Flysch

The oldest unit recognized in this area is a flysch consisting of grey to blackish pyritic shales and siltstones with intercalations of micaceous sandstones and hybrid arenites. This unit is well exposed along the right bank of the Torrente San Calogero. The age of this unit, based on conodonts, is Lowermost middle Permian (Gullo 1993). In the Torrente San Calogero section similar deposits appear as a chaotic clayey mass containing sandstone blocks. The age of the clayey matrix is the same of the flysch deposits on the basis of conodonts (Catalano *et al.* 1991). Scattered small elements of dark grey calcilutites with circumpacific radiolarians of Early Kungurian age suggest that these deposits have been affected by synsedimentary sliding and reworking (Olistostrome Unit *sensu* Catalano *et al.* 1991).

RUPE DEL PASSO DI BURGIO LIMESTONES

Stratigraphically younger deposits consisting of white to grey ammonoid-bearing calcilutites with intercalations of reworked skeletal calcarenites are found in the Rupe del Passo di Burgio block. A Wordian age of these deposits is supported by the rich fossil association characterized by ammonoids, holoturian sclerites, ostracods, crinoid ossicles, fusulinids and conodonts (Gemmellaro 1887-1899; Müller 1956; Bender &

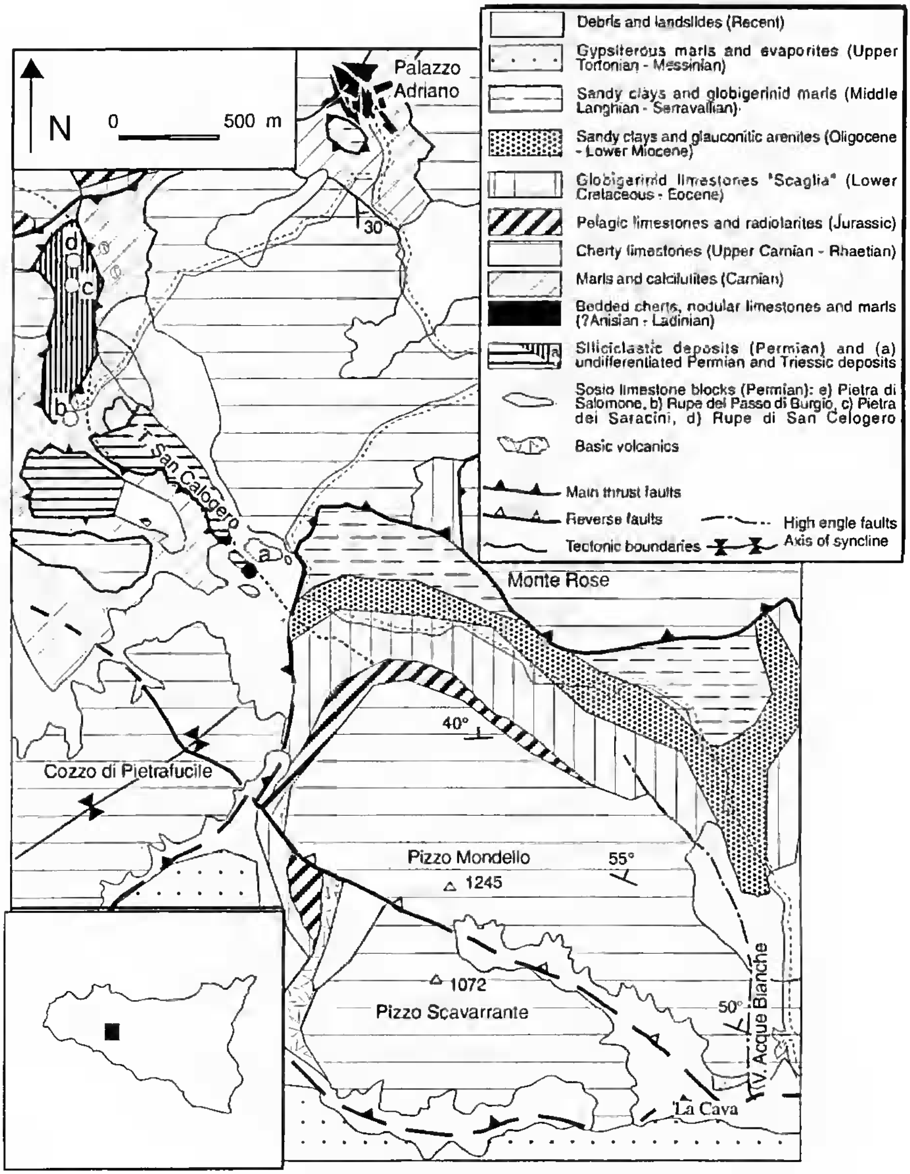

FIG. 3. — Geologic map of the Palazzo Adriano area.

Stoppel 1965; Catalano *et al.* 1991, Kozur 1993a). The Rupe del Passo di Burgio Limestones can be interpreted as hemipelagic carbonates deposited in a distal slope area in which skeletal material, produced in an adjacent platform, was transported downslope by turbidity currents and grain flows. Ammonitic limestones of Wordian age are also described from the Passo di Burgio area, south of the Pietra dei Saracini block (Kozur 1995).

WORDIAN CLAYS

Yellow to grey clays with Wordian conodonts are found in the Sosio Valley in a small outcrop close to the Rupe del Passo di Burgio (Catalano *et al.* 1991).

PIETRA DI SALOMONE LIMESTONES

These deposits characterize the most famous and fossil-rich limestone block outcropping in the Sosio Valley and two smaller blocks present along the Torrente San Calogero valley, known as Pietra dei Saracini and Rupe di San Calogero (Fig. 3). After Gemmellaro's careful descriptions (1887-1899) many paleontological studies were carried out on these limestones, previously regarded as reef limestones (see references in Mascle 1979 and in Flügel *et al.* 1991).

Recent sedimentological and stratigraphic contributions indicate that the Pietra di Salomone Limestones are composed by generally poorly defined thick and, in places, graded beds of coarse calcareous breccias, alternating to skeletal packstone/grainstone beds (Di Stefano 1990; Flügel *et al.* 1991). The latter deposits prevail in the upper part of the Pietra di Salomone block giving rise to a fining-up sequence. The maximum thickness of these deposits is estimated at about 70 m. The breccia elements consist of platform-slope derived carbonates. Reef-derived boundstones/rudstones prevail but also floatstones and grainstones are commonly observed. Sponges, *Tubiphytes*, *Archaeolithoporella*, phylloid algae, richthofenid brachiopods are the main frame-building organisms, associated to highly-diverse fossil assemblages comprising fusulinids. The age of most of the elements ranges from the Artinskian to the Djulfian. A Late Permian age of the matrix is suggested by fusulinids and conodonts occurring with a large mass of reworked Middle Permian faunas (Flügel *et al.* 1991).

The Pietra di Salomone Limestones represent debrite and turbidite sediments deposited in a base-of-slope position. These rocks formed carbonate aprons that could have been accumulated adjacent to or interlayered with the *Red Clay* Unit (see below).

RED CLAY UNIT (Catalano *et al.* 1991)

This is the youngest Permian unit present in the Sosio area, outcropping along the Torrente San Calogero and between the Rupe del Passo di Burgio and the Pietra dei Saracini localities (Gullo & Kozur 1992). It consists of red clays containing fine-grained siliciclastic and carbonate turbidites. A rich pelagic fossil content occurs in the red clays, consisting of circumpacific radiolarians, paleopsychrospheric ostracods and conodonts. It indicates a Late Permian (Djulfian to Changxingian) age (Catalano *et al.* 1991; Gullo & Kozur 1992; Kozur 1993b). The calcareous turbidites mostly consist of skeletal grainstones/packstones with abundant foraminifers (*Reichelina* sp.), *Archaeolithoporella*/*Tubiphytes* fragments and conodonts of Late Permian age (Fig. 3).

PALEOGEOGRAPHIC IMPLICATIONS

Facies associations and ages of the Permian deposits from western Sicily coupled with the palinspastic restoration of the thrust pile forming western Sicily segment of the Apenninic-Maghrebian chain, are consistent with the existence of a wide and persistent deep-water basin along the Africa margin since, at least, the Early Permian time (Catalano *et al.* 1989, 1991; Di Stefano 1990, Bernoulli *et al.* 1990; Robertson *et al.* 1991, Blendinger *et al.* 1992; Kozur 1993b; Vai 1994). Siliciclastic turbidites, associated with carbonate turbidites and debrites formed the sedimentary fill of this basin during the Permian. Shallow-water skeletal material and platform-slope carbonates of well-dated Early, Middle and Late Permian ages were almost continuously transported downslope into the basin, indicating the existence of a mixed terrigenous/carbonate

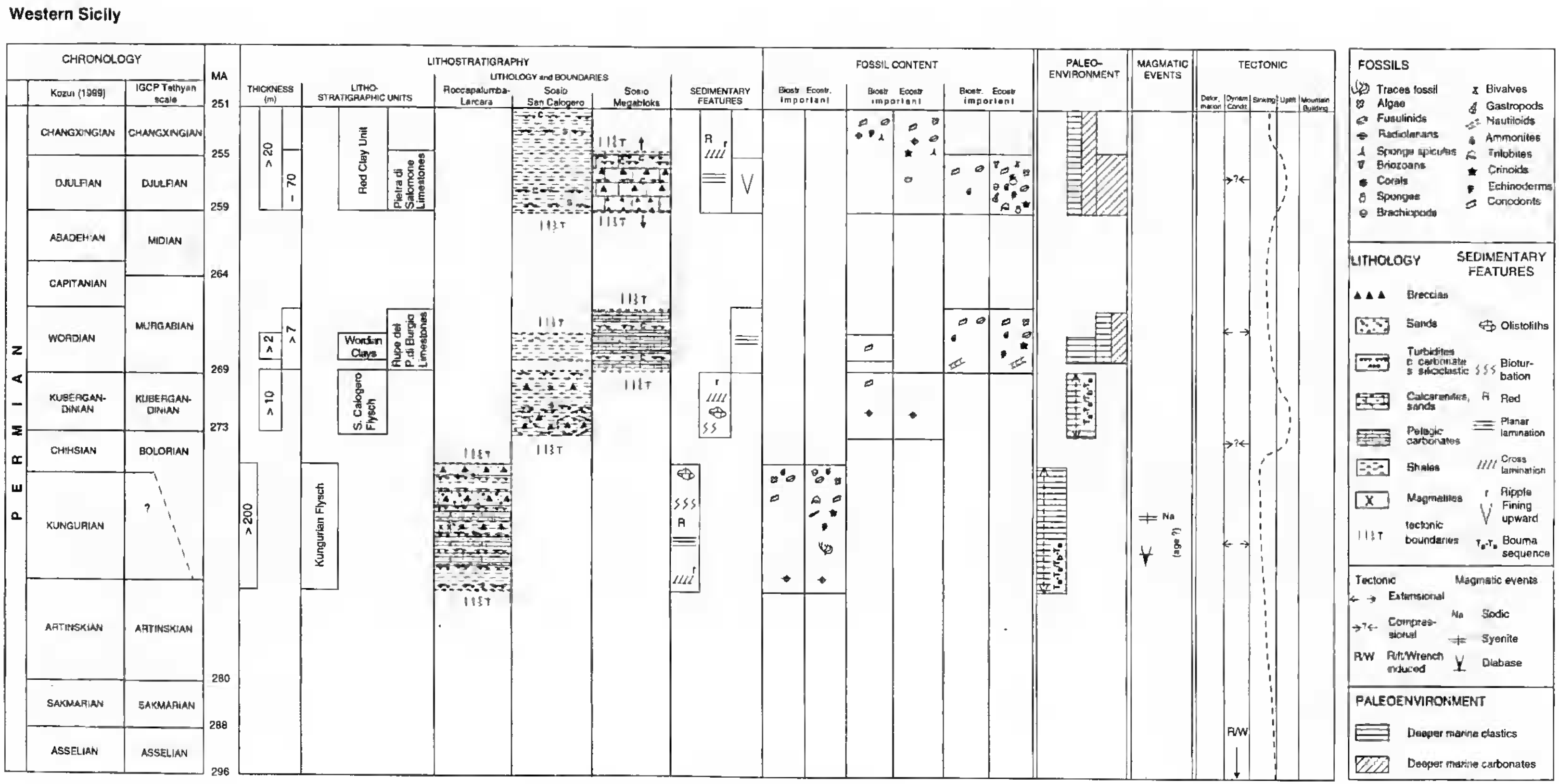

FIG. 4. — Permian lithostratigraphic units of Sicily.

shelf area at the margins of this basin. Part of the clastic carbonates could also have derived from seamount areas inside the basin.

As assumed by Catalano *et al.* (1991), the occurrence of circumpacific deep-water faunas in the Permian deposits of western Sicily suggests a connection of the basin to the Permian Tethys. The most reliable eastward connection of this basin with the oceanic Tethys was through the present-day Ionian basin. This implies a separation of the Adria block from the Gondwanian margin already in the Permian (Vai 1994). Remnants of this basin toward the east are found in Crete (Krahl *et al.* 1986; Kozur & Krahl 1987), Kurdistan (Vasicek & Kullmann 1988) and Oman (Blendinger 1988; Blendinger *et al.* 1992).

The southern edge of the Permian basin of Sicily was represented by the siliciclastic-carbonate platform of Tunisia. Here Middle and Upper Permian deposits, with an upward regressive trend, are well known, reaching a thickness of 6000 m. Facies distribution shows a transition from a reef complex belt to deep-water shaly facies towards the North (Toomey 1991). Remnants of the northern shelf area of the Permian basin of Sicily could be represented by the reworked fusulinid limestones from the Lagonegro basin of the southern Apennines (Donzelli & Crescenti 1970).

The crustal characters of the Permian basin of Sicily are unknown since in the Sicilian chain the sedimentary covers are regionally detached from their original substrate while oceanic crust is well known in the eastern prosecution of the basin (*e.g.* in Oman, Bèchennec 1988).

The Permian basin could have represented either the southern passive margin of the Permian Tethys or a rifting along the Gondwanian margin connected to the main Tethyan domains (Catalano *et al.* 1989, 1991). Crustal extension along the Gondwanian margin could also have been induced by Late Paleozoic mega-shears between Gondwana and Laurussia (Ricou 1994; Vai 1994). The Permotriassic deep-water deposits of Sicily predate, at the Late Carboniferous-earliest Permian time, the extensional phase affecting the Gondwanian margin since the oldest recognized lithostratigraphic unit is a flysch of Kungurian age and thus older syn-rift deposits must have originally underlain the flysch sequence.

Acknowledgments

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